

THE STANFORD EQUIVALENCE PRINCIPLE PROGRAM

PAUL W. WORDEN JR., C. W. FRANCIS EVERITT, AND M. BYE
Physics Dept., Stanford University

503804/K

The Stanford Equivalence Principle Program (Worden, Jr. 1983) is intended to test the uniqueness of free fall to the ultimate possible accuracy. The program is being conducted in two phases: first, a ground-based version of the experiment, which should have a sensitivity to differences in rate of fall of one part in 10^{12} ; followed by an orbital experiment with a sensitivity of one part in 10^{17} or better. The ground-based experiment, although a sensitive equivalence principle test in its own right, is being used for technology development for the orbital experiment.

A secondary goal of the experiment is a search for exotic forces. The instrument is very well suited for this search, which would be conducted mostly with the ground-based apparatus. The short range predicted for these forces means that forces originating in the Earth would not be detectable in orbit. But detection of Yukawa-type exotic forces from a nearby large satellite (such as Space Station) is feasible, and gives a very sensitive and controllable test for little more effort than the orbiting equivalence principle test itself.

The present limit on violations of the equivalence principle is a few parts in 10^{11} . The orbital version of this experiment may improve on this by a factor of a million, allowing very significant tests of several theories. Proper choice of materials for a particular test can enhance this improvement significantly; to check the gravitational response of the strong interactions one could use test masses of copper and hydrogen to gain an additional factor of 30. In 1955, Lee and Yang predicted an apparent violation of the equivalence principle (due to a new long-range force) to explain proton stability. The force has never been detected, but neither has the decay of a proton: the question of a new force therefore becomes more interesting. Moffat's Nonsymmetric Gravitation Theory (Moffat 1987) predicts a $1/R^5$ component of gravity that would be easily detectable in a slightly eccentric orbit. Both of these theories would be strongly tested by the orbital experiment.

We think of the experiment as a highly refined version of Galileo's supposed experiment at the Leaning Tower of Pisa. Two masses fall with slightly different accelerations; the separation between them is proportional to the distance of fall. In the orbital experiment (Fig. 1), the masses fall all the way around the Earth, repetitively. The sensitivity of the experiment depends less on being able to measure their separation than on being able to guarantee that they are not disturbed by uninteresting effects. The key to this is to put the test masses in a "drag-free" spacecraft, which, in its simplest form, is a shield that flies along with them and protects them from gas drag and the environment. The spacecraft body keeps up with the test masses, by means of small jets, without disturbing them. Another consideration is the effect of gravity gradients. If the masses are not at the same height, they will have different accelerations due to the Earth's gravity gradient. The difference in acceleration from gravity gradients has half the period of the orbit, while any signal from a violation of equivalence will have the same period as the orbit. It is therefore possible to separate the gravity gradient acceleration from the equivalence principle signal and use it as an error signal to force the centers of mass of the test bodies into coincidence. The effect of gravity gradients then

REFERENCES

- Lee, T.D. and Yang, C.N. 1955, *Phys. Rev.*, **98**, 1501.
 Moffat, J. 1987, "Test Particle Motion in the Nonsymmetric Gravitation Theory", *Phys. Rev. D*, **35**, 3733.
 Worden, P.W., Jr. 1983, Cryogenic Equivalence Principle Experiment: Discussion and Present Status: Proc
 Third Marcel Grossman Meeting on General Relativity (Hu Ning, Ed.) North Holland, pp. 771-779.

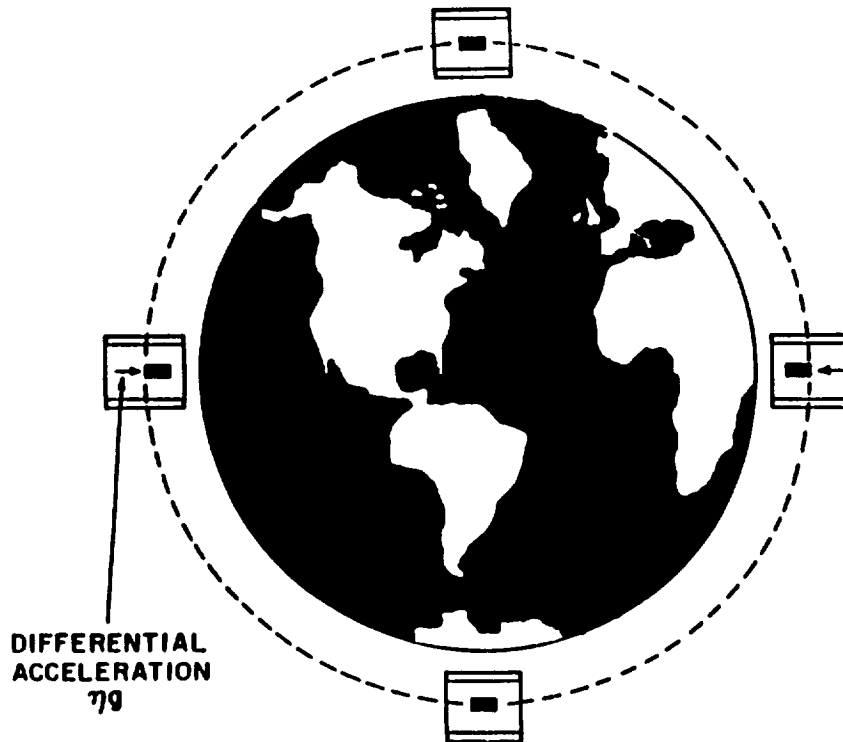


FIG. 1. — Orbital Experiment

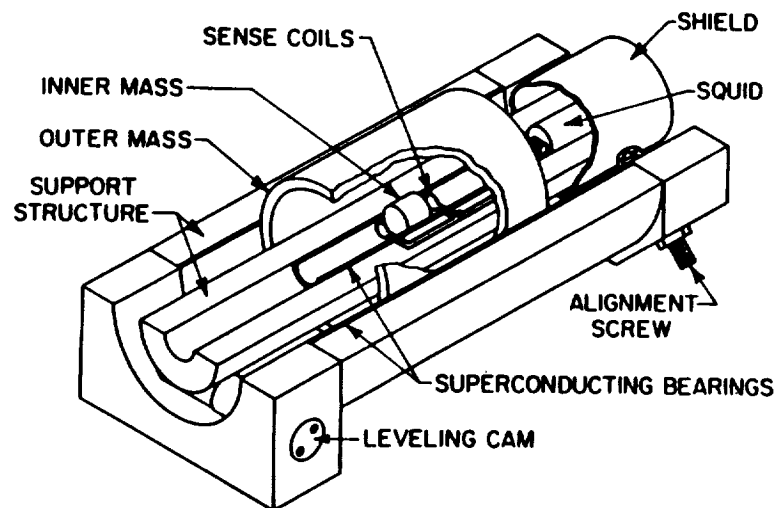


FIG. 2. — Equivalence Principle Accelerometer